An ecological study of a sphagnum lake in the subalpine forest of the Uinta Mountains of Utah

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AN ECOLOGICAL STUDY OF A SPHAGNUM LAKE IN THE SUBALPINE FOREST OF THE UINTA MOUNTAINS OF UTAH

by

Howard C. Stutz

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Botany

June 1951

BRIGHAM YOUNG UNIVERSITY

Provo, Utah
ACKNOWLEDGMENTS

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Chapter</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF ILLUSTRATIONS</td>
<td>iv</td>
</tr>
<tr>
<td>Chapter</td>
<td></td>
</tr>
<tr>
<td>I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Statement of the Problem</td>
<td></td>
</tr>
<tr>
<td>Approach</td>
<td></td>
</tr>
<tr>
<td>Geology and Topography</td>
<td></td>
</tr>
<tr>
<td>Review of the Literature</td>
<td></td>
</tr>
<tr>
<td>II. METHODS USED IN THE STUDY</td>
<td>7</td>
</tr>
<tr>
<td>Analysis of the Water</td>
<td></td>
</tr>
<tr>
<td>The Soil</td>
<td></td>
</tr>
<tr>
<td>The Vegetation</td>
<td></td>
</tr>
<tr>
<td>III. RESULTS</td>
<td>14</td>
</tr>
<tr>
<td>The Chemical and Physical Properties of the Water</td>
<td></td>
</tr>
<tr>
<td>Properties of the Soil</td>
<td></td>
</tr>
<tr>
<td>Nature of the Vegetation</td>
<td></td>
</tr>
<tr>
<td>Miscellaneous Results</td>
<td></td>
</tr>
<tr>
<td>IV. DISCUSSION</td>
<td>37</td>
</tr>
<tr>
<td>The Ecological Forces Within the Lake</td>
<td></td>
</tr>
<tr>
<td>Hydarch Succession</td>
<td></td>
</tr>
<tr>
<td>V. SUMMARY</td>
<td>47</td>
</tr>
<tr>
<td>APPENDIX</td>
<td>49</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>53</td>
</tr>
</tbody>
</table>
LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Bottom contour and vegetational zones of Moss Lake</td>
<td>12</td>
</tr>
<tr>
<td>2.</td>
<td>Profile of depth of Moss Lake</td>
<td>13</td>
</tr>
<tr>
<td>3.</td>
<td>Dissolved oxygen content of the waters of Moss Lake</td>
<td>15</td>
</tr>
<tr>
<td>4.</td>
<td>Temperature of water of Moss Lake at 7 A.M., Aug. 12, 1949</td>
<td>17</td>
</tr>
<tr>
<td>5.</td>
<td>Temperature of water of Moss Lake at 7 P.M., Aug. 12, 1949</td>
<td>17</td>
</tr>
<tr>
<td>6.</td>
<td>Crustacean species and quantities of Plankton in Moss Lake</td>
<td>17</td>
</tr>
<tr>
<td>7.</td>
<td>Organic matter content of soils around Moss Lake</td>
<td>19</td>
</tr>
<tr>
<td>8.</td>
<td>Profile of the depth of organic soil along Transects 1-4</td>
<td>21-22</td>
</tr>
<tr>
<td>9.</td>
<td>Distribution by density of some dominant species along Transect 1</td>
<td>31</td>
</tr>
<tr>
<td>10.</td>
<td>Distribution by density of some dominant species along Transect 2</td>
<td>32</td>
</tr>
<tr>
<td>11.</td>
<td>Distribution by density of some dominant species along Transect 3</td>
<td>33</td>
</tr>
<tr>
<td>12.</td>
<td>Distribution by density of some dominant species along Transect 4</td>
<td>34</td>
</tr>
<tr>
<td>13.</td>
<td>Types and sizes of trees comprising forest</td>
<td>35</td>
</tr>
</tbody>
</table>
CHAPTER I

INTRODUCTION

Statement of the Problem

The Uinta Mountains are of such a nature as to offer a unique field for ecological investigation. They are the only mountains in Utah having an east-west axis, being in sharp contrast to the north-south axis of the rest of the Cordilleran system. They possess thousands of lakes sustained in glacial basins and support Utah's only typical northern Rocky mountain flora. Since the core of the range, and the bulk of the exposed ridges and peaks consist essentially of precambrium quartzite, the waters are not charged with carbonates and the soils and lakes have become acid. Much of the range has been designated by the U. S. Forest Service as a primitive area in which no roads have been constructed and no grazing of domestic livestock permitted. These characteristics make the Uinta Mountains a choice site for study of the ecological factors and their influence on the biotic communities.

A moorland lake in the Grandaddy Lakes Basin was selected as a type area in studying the ecological picture of the lakes characteristic of the Uinta Mountains. This lake, which is one of the hundreds of such lakes in these mountains, is situated in a large basin some twelve miles across each way which drains to the east by way of Rock Creek and to the southwest by way of the North Fork of the Duchesne River. There are few streams throughout the basin, most of the lakes being fed primarily by subterranean
flow.

The lake is a small body of fresh water about three hundred feet in diameter and a maximum of thirty-one feet in depth. It is essentially circular in outline and has a surface area of about two acres. It is located in Township 1 S Range 10 E, about thirty yards north from the western end of Grandaddy Lake, from which it is separated by a narrow morainic ridge about fifteen feet high. On the west a morainic ridge some three hundred yards wide and sixty feet high separates it from Betsy Lake. The lake has not been previously named (11). The author chooses, therefore, to refer to it as Moss Lake, since in direct contrast to most of the lakes in this area, its entire perimeter possesses a floating sphagnum ledge.

Approach

Three consecutive summers, 1948, 1949, and 1950, were spent in collecting the data presented in this study. During the summer of 1948 a reconnaissance of much of the south-facing slope of the Uinta range was made by the author and his wife. It was at this time that the Grandaddy Lakes Basin was selected as the site for further study. During the summer of 1949, this same party spent nearly three weeks at Moss Lake at which time the bulk of the data was collected. In the summer of 1950, Dr. B. F. Harrison and the author spent one week at the lake collecting additional specimens and contrasting the vernal aspects of the vegetation with those found on the previous trips. Quadrats were laid out in several areas to supplement the earlier studies.

Throughout the study the following ecological measurements were made:

1. Water
a. Temperatures
b. Hydrogen-ion concentration
c. Oxygen content
d. Depth
e. Turbidity

2. Soil
a. Structure
b. Zonation
c. Organic matter content
d. Hydrogen-ion concentration

3. Macroscopic Vegetation
a. Aspects
b. Zonation
c. Succession

4. Plankton
a. Gravimetric analysis
b. Crustaceae forms
c. Abundance of microorganisms

5. Macroscopic Animal Forms

Geology and Topography

The Uinta Mountain Range extends as a unit from Kamas, Utah on the west to Junction Mountain in Western Colorado on the east—a distance of some one hundred sixty miles. In general the main divide is slightly north of the center of the range. Thus, the southern slope is somewhat gentler and longer than the northern slope. The plateau-like divide is highly glaciated with many morainic ridges blocking off the depressions in which
lie the numerous lakes. In the Grandaddy Lakes Basin it has been estimated there are more than one thousand of these lakes (14). The lake under study is one such glacier-formed lake being bounded on all sides by morainic till.

The strata of these mountains are not essentially of different origin from the rest of the Cordilleran system to which they belong (4). However, the fact that their east-west axis lies in sharp contrast to the north-south axis of the entire range, and the fact that there has been no evidence of igneous action connected with their uplift, makes them one of the most interesting and unique ranges in the Cordilleran system (3).

The general topographic aspect of the range has been aptly described by Emmons (3):

Topographically they form a rather flat elliptical dome about 150 miles in length along their main axis and 20-25 miles in average width. The interior of the ellipse has a general level of about 10,000 feet out of which rise sharp narrow ridges and peaks of horizontally bedded quartzite to elevations of 12,000 and 15,000 feet. The plateau-like surface between the peaks consists of series of shallow, glacial basins, well clothed with pine forests and studded with innumerable glacial tarms. The streams that drain these basins run in a series of rapidly deepening canyons with nearly vertical walls that reach depths of 3,000 to 4,000 feet before they emerge into the open plain country on either flank. On the broad flat spurs between these canyons gently sloping Tertiary beds lap over the upturned Mesozoic and Paleozoic to elevations attaining in some places 10,000 feet, which, together with the abundant accumulations of moraine material, eventually mask much of the under geology especially on the northern flank.

According to Forrester (4) there have been a series of three major uplifts in the forming of the Uinta Mountains, and these have been responsible for a maximum uplift of approximately 45,000 feet in the center of the range. Since the major portion of the center of the range now stands some 10,000 feet above sea level there has been perhaps 35,000 feet of material eroded from the top of the range. Indications from the exposed strata on the flanks of the dome show that the eroded beds consisted primarily of
shallow water deposits, in the main sandstones, shales and limestones.

No intrusive rocks have ever been noted in the range but Forrest-er (4) reports that extrusive rocks, chiefly andesites and agglomerates have been found in the extreme west end.

**Review of the Literature**

Although the Uinta Mountains have been of considerable interest to biologists and geologists, no extensive ecological studies have been made of that area.

An early sketch of the climate, geology and incidental vegetational characteristics of the Uinta Mountains was made by Jones (9) in a report to the United States War Department. His chief concern being one of finding suitable trails and agricultural land, little was reported concerning the ecological situations.

Pammell visited the Uinta Mountains in 1902 and in 1913, following which he published two papers on his studies (12, 13). In his earlier study he described ecological habitats and listed the plants which he found from the lowland meadow to the top of the Uinta Mountains as encountered in Black's Fork Canyon (12). His later paper contained a list of grasses found in the Wasatch and Uinta Mountains in Utah (13).

Cottam (2) collected plants in the Uinta Mountains and reported some notes on the outstanding features of the vegetational types.

Tanner (14), together with Hansey and three graduate students, conducted a survey of a number of the Uinta lakes with a view to determining their capacity to support game fish. A list of the plants and animals encountered within the waters was published and the lakes were classified as reservoir lakes, rocky-shore lakes, and sphagnum or moorland lakes.
Hales (6) in an unpublished survey expanded earlier work of Tanner to include a rather complete chemical analysis of the water of lakes and streams in the Wasatch Forest which included some of the Lakes of the Grandaddy Lakes Basin.

Graham (5) made what is perhaps the most comprehensive study of the Uinta Basin yet conducted. In a series of three expeditions he collected well over a thousand species of plants and noted some ecological features existing within the major altitudinal vegetational zones. His study was concerned primarily with the lowland Uinta Basin and southern slopes of the Uinta Mountains. Apparently he did not visit the Grandaddy Lakes Basin.

A study of the biotic communities of the Uinta and Southern Wasatch mountains conducted by Hayward (8) furnished a picture of the major biotic aspects of the organisms found in these two areas. However, his study was confined primarily to the Wasatch Mountains and the extreme west end of the Uintas. The environs of these areas are somewhat divergent from that of the High Uintas in which this study was conducted.

Harrison has done considerable work at the extreme western end of the range especially at Trial lake and at Diamond lake and also toward the eastern end of the range in the region of the Atwood and Chain lakes. None of his data have been published as yet.
CHAPTER II

METHODS USED IN THE STUDY

Analysis of the Water

The surface boundaries of Moss Lake was mapped on graph paper by use of an alidade and a plane table. A one-hundred foot base line was established along the south shore of the lake. Reference points were then established at approximately twenty-foot intervals around the shore line and sighted in with an alidade from each end of the base line. These points were mapped in and numbered counter clockwise consecutively from one to forty-five (Fig. 1). A boat was then employed to traverse the perimeter of the lake and the shoreline between each pair of stakes was drawn in freehand.

In mapping the contour of the bottom, six transects were made in a radiating pattern from stake 44. Measurements were made at thirty-foot intervals along transects established between stake 44 and each of the following stakes: 9, 13, 17, 24, 30, and 32. In the determination of bottom depth, a flat board eight inches wide and twelve inches long was weighted and lowered with a rope until the board rested flatly on the bottom. Comparable depths were plotted on a surface map and contour lines of six-foot intervals were drawn (Figs. 1 and 2).

The slope of the shores around the lake was determined at each of the vegetational transect lines by means of a Brunton pocket transit used as a hand level. The elevation above the water level of each of the transect plots was noted and indicated in conjunction with the vegetational and
soil analysis.

The oxygen content was determined by the Rideal-Stewart modification of Winkler method for dissolved oxygen determination (1). The samples were obtained by use of a sampler designed as follows: two bottles, the volume of one being one liter, the other two hundred fifty milliliters, were secured in a wooden frame and connected by means of a rubber tubing attached to short lengths of glass tubing extending through rubber stoppers. A second piece of glass tubing in the stopper of the larger bottle was connected to a thirty-five foot length of rubber tubing. This apparatus was weighted and suspended from the top by a length of rope marked off in one-foot gradations. This design enabled the operator to lower the bottles to any given depth. By shutting off the upper end of the rubber tubing the apparatus could be lowered without water entering the bottles. With release of the tubing, the water at the desired level was admitted first to the small bottle from which it passed into the larger bottle. By the time the larger bottle was filled the water of the smaller bottle had been completely changed more than four times, thus discounting any great error which may have been associated with direct sampling with a single bottle. Samples were obtained from Moss Lake along the established transect between stakes 44 and 24. In most cases at least two samples were taken from the same location. Readings were made at thirty-foot linear intervals except where the lake was shallower than six feet in which case readings were obtained at the bottom and the depth interval noted. Samples from Grandaddy Lake were gathered at random distances from the shore at the surface, at six-foot, at twelve-foot, at eighteen-foot, and at twenty-foot depths.

In order to account to some extent for the influence of diurnal temperature changes of the water, temperature readings were obtained at
seven o'clock in the morning and again at seven o'clock in the evening of the same day.

Plankton samples were taken at ten-foot depth intervals at one hundred ninety-six feet from the south shore. The oxygen-content sampling-bottle was used to obtain water samples for examination. Eighty quarts of water were poured through a fine silk plankton net in the end of which was secured a collecting tube. After collection, a few drops of weak formalin was added to each sample as a preservative. The plankton content of the samples was measured gravimetrically for abundance comparisons. Identification of component crustacean species was made by H. A. Kiser.

Other animal forms within the lake were observed during the course of the study.

When samples of water were collected for oxygen determinations, one cubic centimeter quantities from each of several samples were transferred by means of sterile pipettes to separate dilution bottles containing sterile nutrient agar. Similarly one cubic centimeter quantities from each of these same samples were transferred by means of sterile pipettes to dilution bottles containing sterile Sabouraud's agar. These inoculations were made from samples from the surface and at the deepest depths, both near the center of the lake and near the shore.

Turbidity readings were obtained on Moss Lake and on Grandaddy Lake by use of a Secchi disc lowered at various locations.

The Soil
The soil was studied in relation to its texture, color, zonation, organic content and hydrogen-ion concentration. The texture, and color were noted in the field during the collection of the samples which were
used for further laboratory analysis. The samples were obtained with a Davis peat-borer and collected in seamless soilcans. They were transported to the laboratory, dried for twenty-four hours at one hundred five degrees Centigrade, weighed, ignited for two to three hours, reweighed and the loss in weight computed in terms of percentage loss. The loss on ignition was assumed to be principally organic material. Although other substances might also be lost, during ignition the organic matter content is so high in these soils and since the mineral constituent of these samples is primarily siliceous in nature, the error in these computations is probably not significant for this study. The soil samples collected for hydrogen-ion concentration determination were obtained in glass bottles in the field and a Beckman pH-meter was used several days later in the laboratory for determinations. In preparation of the soil for pH analysis, they were mixed well with an equal volume of distilled water, allowed to settle and the hydrogen-ion concentration of the supernatant liquid determined.

The depth of the peat soils about the lake was determined at each transect plot location by use of the peat-borer rods. In most cases where gradations toward shallow peat away from the shore is not evident, the apparent discrepancy is likely due to some solid object preventing penetration of the measuring rod. In several cases it was conjectured, and in some cases verified by use of the auger itself, that the rod struck tree trunks or branches which were of such size as to prevent detour without considerable displacement of the measurement.

The Vegetation

The vegetation was studied with a view to analyzing the existing flora as it is now represented in the area and also the pattern of hydrophytic succession which is occurring. Collections were made on two different
occasions: during the first part of August, 1949, and during the first part of July, 1950. This allowed for the collection of most of the species while they were flowering.

Transects were laid out on each of the four sides of the lake. The transect lines were begun at stakes 40, 10, 24, and 33, and were directed at right angles to the water's edge toward the forest. Along these transect lines, quadrats twenty-five centimeters long and twenty centimeters wide were outlined generally at fifty centimeter intervals. Where the vegetation was rather uniform for some distance the interval between plots was increased to one hundred centimeters. The species within each of these transects were then listed and counted and their density estimated. The distribution of species along the transects was thus recorded.

The vegetation was distributed in somewhat distinct zones in and around the lake in areas of contrasting water depth, water availability, and elevation of the soil above the water. These zones were designated as (1) submerged unattached, (2) submerged attached, (3) floating attached, (4) flooded sedge meadow, (5) wet meadow, (6) dry meadow and (7) mesophytic conifer forest. The extent of these zones about the lake were mapped (Fig. 1). In order to record any species not encountered in the quadrats a general survey of the zones surrounding the lake was made, the dominants in each of these zones were listed and their relative abundance estimated. The principal plant species of each zone were listed and rated according to their abundance into the following classes: very abundant, abundant, frequent, occasional and seldom.

As a means of sampling the forest vegetation, quadrats one hundred twenty centimeters square were constructed at selected sites throughout the forest floor and the species listed and counted within these quadrats.
Fig. 1. Bottom contour and vegetational zones encountered within and around Moss Lake.
The forest dominants were counted by constructing two quadrats each thirty meters square in two different forest areas. One quadrat was located on a dry rocky moraine beside Moss Lake; the other was located deep in the forest alongside a wet meadow. The three forest dominants, *Picea Engelmannii*, *Abies lasiocarpa*, and *Pinus murrayana* were counted in respect to (1) the number of plants less than four feet tall, (2) those from four feet to maturity (about twenty feet), and (3) mature to old and dead individuals.
CHAPTER III

RESULTS

The Chemical and Physical Properties of the Water

The lake is essentially circular in outline with a diameter of about three hundred feet and an area of about two acres. The bottom is somewhat bowl-shaped with a maximum depth of thirty-one feet. It is shallower toward the east and north with the deepest area a little south of the center.

Series of water samples collected from the same location within the lake during a four day period showed relatively constant agreement in the dissolved oxygen content of the samples, with variations not in excess of nine percent of the first reading. In some cases the series of samples from a given location was obtained at different hours of the same day, in others they were obtained on different days. Some of the series consisted of only two samples. The results appearing in Fig. 3 show an average of the determinations derived from each location.

The top eighteen feet of water show a rather slow and gradual decrease in dissolved-oxygen content from the top downward with a gradient of about 0.1 parts per million oxygen per foot. From the eighteen-foot level toward the bottom the oxygen content decreases rapidly, the gradient increasing sharply to about 0.45 parts per million oxygen per foot. This high gradient diminishes again near the bottom. In the deeper parts of the lake the dissolved-oxygen content drops down to less than 0.5 parts per million at the lowest levels. In the shallower areas of the lake the
Fig. 3.—Dissolved oxygen content of the waters of Moss Lake as determined in samples collected at thirty foot intervals along a transect across the lake between stakes 44 and 24 and at depth intervals of six feet. The figures shown are averages of several determinations obtained during a four day period. The figures on the left are from the south shore and proceed from left to right with increasing distance toward the north shore.

The oxygen content of the bottom waters is rather high so that a horizontal stratification is the case rather than a stratification parallel to the lake bottom.

The Secchi disc determinations of the turbidity of the water were recorded on three different occasions at various locations within the lake. Each recording showed a turbidity depth of seventeen feet.

The hydrogen-ion determinations showed the waters at the shore line to have a pH of 6.5 to 6.8. Samples collected at other points in the lake were necessarily retained for such a period of time before determinations were accomplished as to render the results invalid. These results are not included.

The temperature readings in Moss Lake show an epilimnion of about six feet, an hypolimnion of about eight feet and a somewhat wider thermocline belt in between. Sample intervals were too wide to give a detailed layerage picture but the thermocline gradient appears to be about one degree per foot.
The diurnal temperature changes were limited to the upper six feet (Figs. 4, 5).

The plankton samples collected showed three species of Crustaceans: *Diaptomus lintoni*, *Daphne longispina longispina*, and *Helepedium gibberum*. *Diaptomus lintoni* alone, was found in the surface samples; at the lower depths, all three species were present. A large number of midge larvae were present in all of the samples and were especially abundant at the bottom. The gravimetric measurements of the quantitatively obtained samples show the bulk of the plankton forms to be present at the bottom of the lake. The surface samples contained only 1.7 milligrams of plankton in each twenty gallons of water. At ten feet there were 3.9 milligrams, at twenty feet 15.5 milligrams and at thirty feet 15.6 milligrams in each twenty gallons of water (Fig. 6).

The sterile agar which was inoculated with water samples showed a marked scarcity of microorganisms at all locations. There were a few fungus growths from samples collected from the surface near the shore and a few bacterial growths from all surface inoculations but the other samples showed no growth at all on the agar. Although the results were quite negative for the presence of microorganisms which would grow on the prepared media it should be noted that this procedure did not measure either the acidophilic nor anaerobic microorganisms.

**Properties of the Soil**

The soils are distinctly acid in all areas sampled, ranging in pH from 4.8 at the surface to 5.6 at six feet in the organic soil. The hydrogen-ion concentration was slightly higher near the surface of the peat where actively growing plants were present than in the deeper layers. The
Distance from South Shore

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Fig. 4.—Temperature readings of water of Moss Lake 7 A.M., Aug. 12, 1949. The readings were obtained at thirty foot intervals along a transect between stakes 44 and 24 and at depth intervals of six feet.

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<td>49</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24'</td>
<td>42</td>
<td>42</td>
<td>41.5</td>
<td>42</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>30'</td>
<td>41</td>
<td>41</td>
<td>41.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Fig. 5.—Temperature readings of water of Moss Lake 7 P.M., Aug. 12, 1949. The readings were obtained at thirty foot intervals along a transect between stakes 44 and 24 and at depth intervals of six feet.

<table>
<thead>
<tr>
<th>Sample no.</th>
<th>Depth</th>
<th>Organism</th>
<th>Total Plankton in 80 quarts of water</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>surface</td>
<td>Diaptomus lintoni</td>
<td>.0017 gm</td>
</tr>
<tr>
<td>2</td>
<td>10 feet</td>
<td>Diaptomus lintoni</td>
<td>.0039 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daphne longispina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sules longispina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holopedium gibberum</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>20 feet</td>
<td>Diaptomus lintoni</td>
<td>.0155 &quot;</td>
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<td></td>
<td></td>
<td>Daphne longispina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>sules longispina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holopedium gibberum</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>30 feet</td>
<td>Diaptomus lintoni</td>
<td>.0156 &quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Daphne longispina</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>sules longispina</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holopedium gibberum</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6.—Crustacean species and gravimetric quantities of Plankton collected within the waters of Moss Lake at ten foot intervals near the center of the lake.
mineral soil showed a pH of 5.0 at the surface. In all cases the soil tested showed a lower pH value than did the water of the lake.

The organic matter content was usually higher near the surface of the soil than at any depth. The most obvious exception to this is the sudden high organic matter content of the sample collected at stake ten transect two at a depth of four feet. It should be explained that at this boring a tree branch was encountered which exaggerates the apparent discrepancy. Other exceptions to the above generalization of a lower percent of organic matter content with depth are probably also due to similar local exaggerations.

The general trend of soils in regard to organic matter content shows a decrease with distance from the open water. Even when restricted to the surface layer this general pattern is evident as is seen in the illustration expressing organic matter content of transect two (Fig. 7). The first plot of the other three transects show exceptions to this pattern, however. It will be noticed that the high mineral content is most marked at the first plot of the transects having the steepest slopes. This irregularity is not present in the other transects (Fig. 7).

A third generalization concerning the percent of organic matter in the soils along the major transects is that the soil in the transects with the steeper gradients have less organic matter and more mineral matter than the soil along the gentler slopes. Thus transects two and four show considerably higher soil ignition losses than do the steeper transects one and three.

Throughout the forest floor, ignited samples indicate a higher organic matter content in soils which lie at a low gradient than corresponding samples on steeper slopes (Fig. 7). There is also evidence of
### SOILS — ORGANIC MATTER CONTENT

<table>
<thead>
<tr>
<th>Location</th>
<th>Transect I</th>
<th>Transect II</th>
<th>Transect III</th>
<th>Transect IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pl. 1 Eige</td>
<td>Depth</td>
<td>Percent</td>
<td>Location</td>
<td>Depth</td>
</tr>
<tr>
<td>of Lake</td>
<td>of Lake</td>
<td>Org. Mat.</td>
<td>Pl. 1 Eige</td>
<td>of Lake</td>
</tr>
<tr>
<td>Face</td>
<td>Sur-</td>
<td></td>
<td>Face</td>
<td>Sur-</td>
</tr>
<tr>
<td></td>
<td>Face</td>
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<td></td>
<td>Face</td>
</tr>
<tr>
<td>15.32</td>
<td>12&quot;</td>
<td>85.47</td>
<td>87.79</td>
<td>12&quot;</td>
</tr>
<tr>
<td></td>
<td>24&quot;</td>
<td>57.91</td>
<td></td>
<td>24&quot;</td>
</tr>
<tr>
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<td>37.54</td>
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<td></td>
<td>48&quot;</td>
<td>53.81</td>
<td></td>
<td>Pl. 3</td>
</tr>
<tr>
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<td>41.96</td>
<td></td>
<td>Pl. 4</td>
</tr>
<tr>
<td></td>
<td>72&quot;</td>
<td>38.59</td>
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<td>Pl. 8</td>
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<td>84&quot;</td>
<td>10.69</td>
<td></td>
<td>Pl. 17</td>
</tr>
<tr>
<td>Pl. 2</td>
<td>200&quot;</td>
<td>Sur-</td>
<td>Pl. 16</td>
<td>360&quot;</td>
</tr>
<tr>
<td>from Lake</td>
<td>Face</td>
<td></td>
<td>from Lake</td>
<td>Face</td>
</tr>
<tr>
<td></td>
<td>62.50</td>
<td></td>
<td>31.25</td>
<td></td>
</tr>
<tr>
<td></td>
<td>12&quot;</td>
<td>61.39</td>
<td>67.88</td>
<td></td>
</tr>
<tr>
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<td>36&quot;</td>
<td>70.56</td>
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<tr>
<td></td>
<td>60&quot;</td>
<td>58.11</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 7.—Organic matter content of the soils at various depths and at various distances from the open water around Moss Lake as determined by loss upon ignition.
more organic matter in soils in dense forest than in the exposed slopes. As in the other profiles sampled the percent organic matter decreases with depth in the forest soils.

Examination of the soils showed rather well-defined layers throughout the area. In the meadows surrounding the lake the soils were so uniformly high in organic matter as to vary only in their compactness, color and degree of decomposition. The surface soils in these meadows were usually of a light brown color and very porous, being composed primarily of undecomposed sphagnum, herbaceous roots, conifer needles and branches or other such organic litter. The sphagnum-formed layers could usually be distinguished from all others in light of its highly porous structure. In the flooded meadow zones, this sphagnum deposit is lacking and the peat is composed primarily of Carex accumulations. Other formative materials, although less easily distinguished, are well-preserved and form mucky peat down to the depths illustrated in Fig. 8.

The soils of the forest have a shallow dark mantle horizon of two to six inches underlaid by deep gravelly loam containing considerable light red sand. There is abundant penetration of roots throughout this gravelly horizon. In most cases the surface zone is no more than two or
Fig. 8.—Profile of the depth distribution of organic soil along each of the transects at Moss Lake.
Fig. 8 (continued)
three inches thick, whereas the gravelly loam probably extends down to
great distances along the morainic deposits. Many areas within the forest
are almost entirely devoid of the organic mantle except in tiny localized
island accumulations beside larger boulders.

Considerable fine angular sand was found at the bottom of the peat
deposits and also intermingled with the peat along the shores adjoining
the steeper morainic slopes. This was noticeable at the northern shore
of the lake where considerable sand was found, especially in the surface
layers of the peat.

The dry meadow zone has a deep black organic surface mantle of
about four inches overlying the same type of gravelly loam found in the
forest. This top horizon is very highly ramified with numerous fine roots.

The Vegetation

The vegetation of the lake and the surrounding areas falls rather
distinctly into seven zones which are correlated with the depth of the
water in the lake, depth of the water table, and the elevation of the
exposed land (Fig. 1).

The first zone, which is found within the waters of the lake, is
the submerged-unattached zone which is composed primarily of the plankton
forms. They are distributed throughout the entire lake and are most con-
centrated near the bottom.

The second zone is the submerged-attached zone. A belt of Isoetes
bolanderi, the only component species determined in this zone, is found
within the shallow waters from the shoreline to a depth of about ten feet.

Zone three, referred to as the floating-attached zone, is repre-
sented on Moss Lake by Nymphaea polysepala. These plants were abundant at
the shallow eastern end of the lake and twelve individuals were counted at the western end in water about three feet deep. Other lakes in the near vicinity contained other species of floating-attached plants, chief of which was *Sparganium minimum*. Some of the more shallow pools were essentially choked up with those bur-reeds and lily pads.

The flooded meadow, or zone four, was covered with water well into July during 1950. Since its surface is so near the same level as the lake level, it may be that the flooding occurs during any sizeable storm throughout the season. The flora of this zone is quite abruptly distinguished from the bordering wet meadows, the surface of which is some three to eight inches higher than the surface level of the flooded meadow. *Carex aquatilis*, *Carex paupercula*, and *Eleocharis* sp. are the predominant plants in this zone. They are about equally distributed and show a density of about twenty-five to seventy percent.

The principal plants encountered are:

- **Very abundant** . . . . CYPERACEAE
  - *Carex aquatilis* Wahl.
  - *Eleocharis* sp.
  - *Carex paupercula* Michx.

- **Abundant** . . . . . . . CYPERACEAE
  - *Carex illota* Bailey

- **JUNCACEAE**
  - *Luzula piperi* (Coville) Henry

- **Frequent** . . . . . . . JUNCACEAE
  - *Juncus drummondii* E. Mey.

- **SALICACEAE**
  - *Salix chlorophylla* Anders.

- **Occasional** . . . . . . . GRAMINEAE
  - *Alopecurus aequalis* Sobol.

- **RANUNCULACEAE**
  - *Ranunculus reptans* L.
CRUCIFERAE
   Radicula alpina (S. Wats.) Greene

Seldom . . . . . . CRASSULACEAE
   Clementsia rhodantha (A. Gray) Rose

The wet meadow zone, or zone five, has many component species growing so profusely together than in many places one hundred percent ground coverage results. Grasses grow more abundantly here than anywhere else in the area. Pure stands of any one species are not extensive and the heterogenous society form a sod-like mat over the wet soil. The water table is high in this zone and the plant roots are apparently in contact with abundant moisture throughout the entire growing season. This zone is much wider on the gentler slopes at the east and west shores than on the steeper gradients along the south and north shores. Its maximum extension is about eighty feet at the eastern end of the lake. At the north shore the zone is limited to less than two feet in some spots.

The principal plant components are:

Very abundant . . . . SPHAGNACEAE
   Sphagnum acutifolium Enrh.

BRYACEAE
   Pohlia cucullata (Sch.) Bruch.

CYPERACEAE
   Carex nigricans C. A. Meyer

UMBELLIFERAE
   Ligusticum tenuifolium Wats.

COMPOSITAE
   Antennaria corymbosa E. Nels.

Abundant . . . . . . GRAMINEAE
   Agrostis thurberiana Hitch.
   Deschampsia cespitosa (L.) Beav.

POLYGONACEAE
   Polygonum bistortoides Pursh.
RANUNCULACEAE
   Caltha leptosepala DC.

ERICACEAE
   Kalmia microphylla (Hook) Heller
   Vaccinium occidentale A. Gray

GENTIANACEAE
   Gentiana parryi Engelm.

SCROPHULARIACEAE
   Pedicularis groenlandica Retz.

COMPOSITAE
   Erigeron salsuginosus (Richards) A. Gray

Frequent

GRAMINEAE
   Calamagrostis canadensis (Michx.) Beauv.
   Danthonia intermedia Vasey
   Phleum alpinum L.
   Trisetum wolfi Vasey

CYPERACEAE
   Carex illota Bailey

JUNCACEAE
   Juncus mertensianus Bong.
   Luzula piperi (Coville) Henry

ORCHIDACEAE
   Habenaria dilatata (Pursh.) Hook
   Spiranthes romanzoffiana C. & S.

ROSACEAE
   Potentilla diversifolia Lehm.

VIOLACEAE
   Viola macloskeyi Lloyd

ONAGRACEAE
   Epilobium anagallidifolium Lam.

ERICACEAE
   Gaultheria humifusa (Graham) Rydb.
   Vaccinium scoparium Leiberg

GENTIANACEAE
   Swertia scopulina Greene

SCROPHULARIACEAE
   Veronica wormskjoldi R. & S.
Occasional

**CYPERACEAE**
Eleocharis sp.

**JUNCACEAE**
Juncus drummondii E. Mey.

**RANUNCULACEAE**
Ranunculus maximus Greene
Ranunculus eschscholtzi Schlect.

**VIOLACEAE**
Viola ozysepala Greene

**PRIMULACEAE**
Dodecatheon tetrandrum Suksdorf

Seldom

**LILIACEAE**
Veratrum californicum Dur.

**PRIMULACEAE**
Primula parryi A. Gray

**SCROPHULARIACEAE**
Castilleja rhexifolia Rydb.

Zone six is a dry meadow stage made up of a variety of plant species which have growth densities of about five to forty per cent. The principal plant components are blueberry, elephant's head, and several composites which occur typically in families made up usually of a single species with abundant exposed ground between. This zone extends as a rather narrow belt about five to ten feet wide around the lake between the wet meadow and the forest zones. The soil consists of a thin organic mantle some four inches in depth which immediately overlies the gravelly glacial-morainic deposits. The surface has a gradient which allows for thorough drainage.

The plants most commonly found in this zone are:

**CRUCIFERAE**
Draba columbiana Rydb.

**ERICACEAE**
Vaccinium scoparium Leiberg
SCROPHULARIACEAE
   Pedi cularis racemosa Dougl.

COMPOSITAE
   Arnica mollis Hook.
   Erigeron salsuginosus (Richards) A. Gray
   Senecio cymbalarioidea Nutt.

Abundant . . . .

BRYACEAE
   Pohlia cucullata (Schwaegr.) Bruch.

POLYTRICHACEAE
   Polytrichium juniperinum Hedw.

GRAMINEAE
   Poa nervosa (Hook.) Vasey
   Trisetum wolfi Vasey
   Trisetum spicatum (L.) Richt.

CARYOPHYLLACEAE
   Arenaria congesta Nutt.

SAXIFRAGACEAE
   Saxifraga rhomboidea Greene

ERICACEAE
   Gaultheria humifusa (Graham) Rydb.

SCROPHULARIACEAE
   Penstemon whippleanus A. Gray

COMPOSITAE
   Achillea lanulosa Nutt. var. alpicola Rydb.
   Solidago ciliosa Greene

Frequent . . . .

POLYGONACEAE
   Polygonum bistortoides Pursh.

CRASSULACEAE
   Sedum debile S. Wats.

ROSACEAE
   Ivesia gordoni (Hook.) T. & C.

COMPOSITAE
   Antennaria corymbosa E. Nels.

Occasional . . . .

HYDROPHYLLACEAE
   Phacelia alpina Rydb.
The forest floor is made up of several different ecotypes each of which shows a different local vegetative pattern. The plants common to the moist swales are somewhat in contrast to those on exposed slopes and those growing in well-shaded areas differ from those present in open areas. However, the forest understory is somewhat homogenous in that the component species are principally mesophytic herbs, the shrubby stage being entirely absent except for Vaccinium cespitosum and Vaccinium scoparium.

The principal plants belong to this zone are:

**Dominant Trees . . . . PINACEAE**
- Abies lasiocarpa (Hook.) Nutt.
- Picea engelmanni (Parry) Engelm.
- Pinus murrayana Balf.

**Understory Shrubs . . ERICACEAE**
- Vaccinium occidentale A. Gray
- Vaccinium scoparium Leiberg

**Herbs Abundant . . . . GRAMINEAE**
- Poa nervosa (Hook.) Vasey
- Trisetum spicatum (L.) Richt.

**CRUCIFERAE**
- Draba columbiana Rydb.

**SCROPHULARIACEAE**
- Pedicularis racemosa Dougl.
- Penstemon whippleanus A. Gray

**COMPOSITAE**
- Achillea lanulosa Nutt. var. alpicola Rydb.
- Arnica mollis Hook.
- Erigeron ursinus D. C. Eaton
- Erigeron salsuginosus (Richards) A. Gray
Solidago ciliosa Greene

**Frequent**

**SPHAGNACEAE**

Sphagnum acutifolium Enrh.

**BRYACEAE**

Pohlia cucullata (Schwaegr.) Bruch.

**POLYTRICHACEAE**

Polytrichium juniperinum Hedw.

**GRAMINEAE**

Trisetum wolfi Vasey

**POLYGONACEAE**

Polygonum bistortoides Pursh.

**CARYOPHYLLACEAE**

Arenaria congesta Nutt.

**ROSACEAE**

Ivesia gordonii (Hook.) T. & G.

**SCROPHULARIACEAE**

Castilleja luteovirens Rydb.

**CAMPANULACEAE**

Campanula petiolata A. DC.

**COMPOSITAE**

Antennaria corymbosa E. Nels.

**Occasional**

**GRAMINEAE**

Phleum alpinum L.

**JUNCACEAE**

Luzula Piperi (Coville) Henry

**SAXIFRAGACEAE**

Sedum debile S. Wats.

**SAXIFRAGACEAE**

Saxifraga rhomboidea Greene

**ROSACEAE**

Potentilla diversifolia Lehm.

**HYDROPHYLLACEAE**

Phacelia alpina Rydb.

**SCROPHULARIACEAE**

Pedicularis paysoniana Pennell
Fig. 9.—Distribution by density of some dominant plant species along Transect number 1.
Fig. 10.—Distribution by density of some dominant plant species along Transect number 2.
Fig. 11.—Distribution by density of some dominant plant species along Transect number 3.
Fig. 12.—Distribution by density of some dominant plant species along Transect number 4.
TRANSECTS WITHIN THE FOREST

A. Dry gravelly moraine

<table>
<thead>
<tr>
<th>Height</th>
<th>Pinus</th>
<th>Abies</th>
<th>Picea</th>
</tr>
</thead>
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<tr>
<td>Less than 4 feet tall</td>
<td>0</td>
<td>345</td>
<td>16</td>
</tr>
<tr>
<td>4 feet to 26 feet tall</td>
<td>0</td>
<td>232</td>
<td>14</td>
</tr>
<tr>
<td>20 feet to old</td>
<td>0</td>
<td>47</td>
<td>19</td>
</tr>
</tbody>
</table>

B. Moist table land

<table>
<thead>
<tr>
<th>Height</th>
<th>Pinus</th>
<th>Abies</th>
<th>Picea</th>
</tr>
</thead>
<tbody>
<tr>
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<td>18%</td>
<td>45</td>
<td>63</td>
</tr>
<tr>
<td>4 feet to 20 feet tall</td>
<td>72</td>
<td>27</td>
<td>54</td>
</tr>
<tr>
<td>20 feet to old</td>
<td>225</td>
<td>90</td>
<td>36</td>
</tr>
</tbody>
</table>

* These were found mostly along the borders of the open meadows.

Fig. 13.—Types and sizes of trees comprising forest.

Although these seven zones are distinct and easily identified by their general aspects, yet much telescoping of species is common. The dominant species of each zone are distinct and characteristic but often occur in other zones where they assume a different role. Since the water table and elevation of the surface are the main factors in determining the limits of the zones, their abruptness of change is reflected in the zone boundaries. In accordance with this generalization, the zones are much broader and more telescoping of species is present along the gentle slopes than along the steeper gradients. Islands of plant species belonging to one particular zone are found on elevated or depressed spots within the structure of another zone. A striking illustration of this was found around the base of the trunks of trees growing in the wet meadow zone. The roots which were somewhat elevated above the rest of the terrain offered an environment quite strikingly different from the surrounding meadow. On these levels the dry meadow plants accumulated as isolated islands. Another example is well-demonstrated in the lake by floating islands of carex meadow. Dead sphagnum on these islands indicates that they were part of the wet meadow at one time, but due to separation from the shore, they
have submerged to the exclusion of the wet-meadow plants and have formed habitats suitable for the carex-meadow components.
The Ecological Forces Within the Lake

The waters of Moss Lake do not contain great numbers of living forms. Around the shallow portions of the shoreline, invertebrates are quite abundant, but the study showed algae, bacteria, and fungi to be scarce and fishes are absent. Submerged-unattached and floating-attached plants are rare; attached-emergent plants are entirely absent. This dearth of living forms is not surprising in light of the physical and chemical characteristics of the lake. Being acid, cold and low in oxygen, many forms are excluded.

In the superficial examination of the microscopic plants, the relative sterility of the water, especially at the lower depths, was apparent. Any bacteria living on the bottom of the lake would have to be acidophilic, psychrophilic, anaerobic and be able to live in almost complete darkness. Many marine bacteria have been studied which can and do live at great depths in the absence of oxygen and light and where it is cold (15), but extensive studies of acidophilic bacteria have not been made. The waters of this lake are sufficiently acid to limit the growth of microorganisms other than those which are quite acid tolerant. Due to the low temperature, lack of light and low available oxygen, the bacterial population is expectedly low.

Fungal forms are also at a disadvantage in the waters of this lake principally because of the anaerobic conditions. The only obvious source of oxygen to the waters of the lake is from the photosynthetic processes
of the few lily pads, *Isoetes*, and green plankton forms, and through solution from the atmosphere. Since the lake is well-protected from wind action little agitation of the water’s surface ever occurs so that the supply of oxygen from the atmosphere is at a minimum. Since fungi require oxygen, the waters of Moss Lake are not very suitable for their growth. Zobell (15) reported that Baier had indicated in his studies that fungi were unable to compete with bacteria for the oxygen nor for the organic supplies in water. Although the organic matter supply is sufficiently plentiful in Moss Lake, for both bacterial and fungal growth, yet the low oxygen supply probably not only limits the growth of fungi therein, but also even inhibits the growth of most bacterial forms.

It is likely this distinct lack of dissolved oxygen more than any other factor which also limits the fishes in these lakes, no native fishes being found in Moss Lake. A resident of the Uinta Basin indicated to the writer that the lake had been stocked at least once several years ago but that the fish had not survived. With the abundant insect life and vegetable matter around the shores it is evident that the fish did not lack for food.

The lake is as deep as or deeper than the majority of the lakes in the basin (14), and since many of these lakes support fish, the fish in Moss Lake are apparently not excluded because of insufficient depth of water.

It follows then, that the chief limitation to fish culture in this and possibly other sphagnum-bordered lakes of the area may be the lack of dissolved oxygen within the waters. The abundance of midge larvae in the bottom plankton samples is also indicative of this low oxygen content.

The lack of microscopic organisms of decay has probably contributed more than any other single factor to the well-preserved accumulations of organic materials in the lake. Within some of the present lake mud
Deposits may be seen plant remnants in almost perfect preservation. In one place the author uncovered the end of a conifer branch which was buried beneath some twenty inches of organic debris. The needles were still attached and some of the chlorophyll was still present within them. In contrast to this extremely slow decomposition of organic materials in the water, tin-cans which have been thrown into the lake have apparently disintegrated rather rapidly, due presumably to the activity of the dissolved acids of the waters and perhaps to some oxidative processes.

Since the environment limits the microorganisms of decay to a minimum, it may be that chemical decomposition apart from living organisms is the principal decomposing force within the organic accumulation. This chemical decomposition is noticeably very slow, however, due perhaps to the limited dissolved oxygen supply within the waters. The organic debris is apparently accumulating much more rapidly than it is being decomposed.

The source of the organic debris in the lake is primarily from the annual growth of the plants and animals within and around the water. The physical nature of the lake itself has assured some of these accumulations. Trees, for instance, growing along the shore line of the water lean far in toward the lake. Since the open water and the soft muds on the lake-side of the trees do not offer solid support to the roots, the growing trees settle toward the water, being anchored by their roots in the solid ground behind. As the trees continue to grow and become taller the angle of leaning is increased and when weight and leverage exceed the ability of the roots to support it, the tree topples over into the lake. Thus the tree not only prematurely dies and the successional changes accelerated, but their direction of fall is nearly always into the water. The organic contribution to the lake is thereby increased. Another source
of additional organic matter unique to these bog lakes is the organic accumulations from the sphagnum-moss ledges which grow out from the shoreline over the surface of the water.

Inorganic sediments are adding some little bulk to the lake deposits. This supply of alluvial material is greatest from the steeper northern and southern borders of the lake. A comparatively high mineral content was observed in soil samples obtained at the surface right at the water's edge, especially on the northern and southern shores. Apparently the loose fibrous network of the sphagnum mat catches and retains the alluvial materials more so than do the other wet meadow forbs. Since this high mineral content diminishes rapidly in the subsurface layers, the alluvium holding capacity of the sphagnum is apparently lost quickly upon death which results in a breakdown of the fine webby networks. Sand particles, being thus released are then easily washed into the lake by subsequent percolating water. The alluvial accumulations at other points of the lake probably occur primarily during heavy storms or during movements of melting snow and ice in the spring months.

Hydrarch Succession

The open waters of the lake constitute an invasion area for hydrarch pioneers. The plankton forms, representing the unattached-submerged stage, are rather scarce but well distributed. The crustacean species which were collected were distinctly pelagic, the weed-loving Chyadoridae being conspicuously absent (10). The midge larvae, typical of areas low in oxygen, were comparatively abundant in the samples collected, especially in those from the bottom levels. These plankton forms along with other species play a significant role in the water especially in regard to their competition.
for the oxygen supply. However, they are not present in sufficient num-
bers to contribute extensively to the lake bottom accumulations.

The principal plant found growing entirely attached submerged
within the lake is *Isoetes bollanderi* the distribution of which is limited
primarily to the shallower water. Their decaying remains are continually
adding humus to the lake muck but since they are limited in their range
and since so many larger factors are producing the same effect, this reac-
tion is not deemed to be very significant. However, its photosynthetic
process is probably important in adding oxygen to the water.

In the shallow waters, *Nymphaea polysepala* has established itself
in several places. It is found only where the water depth allows it to
send its leaves to the surface. The reactions of these floating-attached
plants exert a significant influence upon the lake itself and upon other
life forms within the lake. Their undersurfaces are choice sites for
leeches and flukes. The broad leaves shade the understory and in dense
populations probably play a major role in differential selection of under-
story plants. Being quite bulky, these lily pads are furnishing some or-
ganic material by way of their annual dead remains. The accumulation of
this and other organic material in time will probably shallow the water
sufficiently for invasion in some places by the flooded sedge meadow to the
ultimate exclusion of *Nymphaea* in their present location but this is not
the usual course of the succession.

The flooded meadow, so called because it is subject to standing
water during a large part of the season, encroaches upon the shallowed
lake wherever the water completely leaves the surface during a part of the
season. The sedges grow rather densely and rank in these flooded areas
and their organic remains accumulate rapidly. Being saturated with water
throughout most of the season, this dead debris is not subject to rapid decomposition. The bacteria and fungi as well as burrowing worms and insects are limited and essentially excluded by the lack of aeration in these water-soaked soils. Whatever organic additions are made, then, are well-preserved and deep accumulations of organic refuse results. When the accumulation is sufficient to prevent flooding from the lake waters, the sedges are replaced by a host of grasses and forbs which are able to invade and compete within the drier environment.

The principal pioneers of the flooded meadow are Carex aquatilis and Carex paupercula with Eleocharis sp. following close behind, as a secondary invader. These pioneers occur around the water's edge wherever the water is below the surface of the soil for about two months of the year. They are bordered on the water-side in places by lily pads which are never left dry and on the land-side by the wet-meadow association which is not immersed during the growing season. Where low stretches reach back from the water's edge, the entire area becomes a flooded Carex-meadow and is occupied by the above mentioned pioneers, along with Carex illota, Luzula piperi, Salix chlorophylla, and Juncus drummondii. Quite an extensive area of this flooded-meadow exists at the eastern end of the lake and is bordered along its entire perimeter by abruptly contrasting wet-meadow flora.

The component species of the flooded meadow add considerable organic debris to the soil by means of their dead roots and aerial parts. When these have accumulated to such a point that the lake water no longer floods it extensively, during the growing season, a multitude of plant species are able to invade. Since the water table is so near to the surface of this zone, it is referred to in this paper as the wet-meadow zone.
The pioneers of the wet-meadow are principally sphagnum and moss (3). Along the flooded-meadow borders, the transition from flooded conditions to non-flooded conditions is very abrupt and the pioneers are quickly replaced by vigorous secondary invaders. These mosses are quite bulky in habit and upon death, decomposition is slow and rapid accumulation follows. The raising of the surface layers above the water level is also greatly enhanced by the increased transpiration of these pioneers whose surface density is near one hundred percent in contrast to about a fifty percent density in the Carex meadows. Thus along the flooded-meadow borders the transition from the flooded-meadow to the drier wet-meadow conditions is very abrupt and the pioneers are quickly replaced.

Along the water's edge of the lake the succession follows a different pattern. Here Sphagnum acutifolium and Pohlia cucullata invade the borders of the open water much as they invade the borders of the Carex meadows but here forming an overhanging shelf. The debris of these pioneers cannot accumulate so rapidly as in the flooded meadow. With rapid transpiration, the available water supply is, applicably speaking, unlimited. Thus the water level beneath the plants is not lowered and secondary invaders cannot compete as favorably as they do on the areas which overlie soil. Wide belts of the Sphagnum-moss pioneers thus develop with only a few secondary invaders, chiefly Vaccinium occidentale, Kalmia microphylla, and a few Luzula Piperi, being able to successfully compete with them. Furnishing their own rooting zones in their amassed dead bodies these plants have grown out in distinct ledges over the water. Their porous nature makes them buoyant enough to float on the surface. The extent of these green moldings is probably limited, except by biotic influences, only by the physical forces of their environment such as wind, ice and snow which may
act to sever them from the shore. Several sizeable pieces of floating meadows thus formed, are present on the surface of the lake. Many of these detached islands have become saturated with water to the extent that they have sunken below the tolerance of the wet-meadow pioneers and there has been a successional retrogression back to the flooded-carex-meadow stage. It is quite probable that ultimate saturation has caused sinking of all component plants of other similar islands and their remains thereby added to the organic lake muds.

The reactions of the wet-meadow components alter the substrata in which they are established principally in adding organic matter to it and in lowering the moisture content of it. Harrison (7) reports that in a study of Diamond Lake, at the western end of the Uinta Mountains, the moisture content in comparable levels of the peat soils diminished rather rapidly away from the water's edge, due presumably to transpiration losses of the plant inhabitants. The rapid accumulation of organic debris, accompanied by high transpiration losses, transforms the wet-meadow zones into habitats suitable for new invaders. However, with an abundance of plant species present, new invaders have difficulty in getting established. With the reactions of the inhabitants constantly building the soil surface higher and thereby drier, there comes a time when they have so altered the environment that the dry meadow pioneers are able to successfully invade and become stabilized. The wet-meadow components are unable to withstand the longer periods of drought which exist on these now better drained slopes so that gradually they are replaced by blueberries, mustards, wheat grasses, young conifers and other comparatively more xeric species.

The dry meadow exists as a distinct belt lying transitionally between the established forest on one side and the wet meadow on the other.
It is represented by plants which exhibit considerable tolerance both to drought and exposure. With invasion of the taller forest species, much of the selective action of exposure and competition is removed and other plants now extend into the area and become established as the understory of the forest.

The conifer forest with its component understory is thus able to invade successfully the dry meadow zone and in many places has considerably narrowed the dry meadow belt. Many of the component species of the dry meadow are able to exist within the forest understory and become principal components of it. Other species, however, such as spring beauty, buttercups and fleabane are limited to the forest zone. This conifer forest with its accompanying understory, constitutes the climax vegetation of the area.

The three dominant components of the climax forest are Pinus murrayana, Abies lasiocarpa and Picea engelmanni. Extensive pure stands of any of these trees are not found in the basin but local spots may exhibit almost pure stands of one or another. In most areas the three are growing side by side, in clumps, or within a relatively near radius of each other.

The shallow root system of Pinus murrayana allows it to grow well down into the meadows, sometimes very near to the water's edge. Keen competition by the meadow dominants, however, have limited the invasion of the seedlings on the wetter portions. In some areas the pines have formed rather good stands along the upper gradients of the meadow and below the drier knolls. The pines are not prevalent on the more exposed slopes and exist on the mineral soils only when contiguous with some of the other conifers. This species may not represent a true climax species.
Abies lasiocarpa forms almost pure stands on many of the exposed ridges throughout the basin. The seedlings and young trees show successful migration throughout the open areas which overlie mineral soil. Some isolated trees which have developed on deep organic soils in the meadows indicate that the fir is not limited in its migration toward the wet meadow so much by the environment present as by the competition of the established flora. Being able to become stabilized on the exposed areas under comparatively adverse conditions, the fir represents the forest's xeric-pioneer much as the pine is the forest's hydric-pioneer.

The predominant mesophytic forest climax species is Picea engelmanni. These spruce are somewhat intermediate between the pine and fir in their limits and adaptabilities. They are at their best on deep rich loamy soils of high moisture content. They are apparently very tolerant of altitude, being almost always present at the timberline limits. They do not invade the wet meadow nor can they endure the thin mantled morainic ridges. However, since the wet meadow is developing toward a mesophytic environment, due primarily to the accumulation of organic sediment and since the xerophytic ridges and slopes are developing toward the mesophytic environment due to weathering and the accumulations of organic materials which are mellowing the adverse edaphic conditions, the ultimate overall climax mesophytic conditions will well harbor the spruce as the dominant climax species. Pinus murrayana and Abies lasiocarpa will probably always represent a sizeable component of the forest however, due to the ever-present minute ecological islands within it, such as springs, slopes and exposures.
CHAPTER V

SUMMARY

1. A study was made of the ecology and floristics of a small bog lake referred to as Moss Lake, in the Grandaddy lakes region of the Uinta Mountains, Utah.

2. Most of the lakes of the area are contained in glacial basins scooped out from pre-cambrian quartzite.

3. The waters and soils of the area are acid.

4. There is a slow rate of organic decomposition within the waters and within the soil in the area studied, which has resulted in the formation of peat deposits.

5. A distinct floating edge of sphagnum peat extends out over the water from the shore around the entire perimeter of Moss Lake. The tenacious entanglement of the buoyant dead remains of Sphagnum acutifolium and Pohlia cucullata forms a floating rooting zone for these mosses.

6. The basin in which the lake is formed, is being filled in by: (a) alluvial deposits, (b) organic debris from plants within the water and forest species around the shores, (c) migration of the carex meadows toward the open waters, and (d) encroachment of floating sphagnum-moss ledges upon the waters. When the time is reached that the central borders of these floating ledges approach each other, the lake will become a typical floating peat bog which will be invaded by succeeding stages of succession.

7. The hydroseric succession consists of the following stages: submerged-unattached, submerged-attached, floating-attached, flooded sedge-meadow, wet-meadow, dry-meadow, mesophytic conifer forest.
The climax mesophytic forest is composed of three dominant species, viz., Picea Engelmanni, Pinus Murrayana, Abies lasiocarpa.
APPENDIX

LIST OF PLANT SPECIES COLLECTED

Sphagnaceae

Sphagnum acutifolium Enrh.

Bryaceae

Pohlia cucullata (Schwaegr.) Bruch.

Polytrichaceae

Polytrichium juniperinum Hedw.

Isoetaceae

Isoetes bolanderi Engelm.

Pinaceae

Abies lasiocarpa (Hook.) Nutt.
Picea engelmannii (Parry) Engelm.
Pinus murrayana Balf.

Sparganiaceae

Sparganium minimum Fries

Gramineae

Agrostis thurberiana Hitch.
Alopecurus aequalis Sobol.
Calamagrostis canadensis (Michx.) Beauv.
Danthonia intermedia Vasey
Deschampsia cespitosa (L.) Beauv.
Phleum alpinum L.
Poa nervosa (Hook.) Vasey
Trisetum spicatum (L.) Richt.
Trisetum wolfi Vasey

Cyperaceae

Carex aquatilis Wahl.
Carex illota Bailey
Carex nigricans C.A. Meyer
Carex paupercula Michx.
Cyperaceae (cont.)

*Carex praegracilis* W. Boot.

*Eleocharis sp.* (immature)

**Juncaceae**

*Juncus drummondii* E. Mey.

*Juncus mertensianus* Bong.

*Luzula piperi* (Coville) Henry

*Luzula spicata* DC & Lam.

**Liliaceae**

*Veratrum californicum* Dur.

**Orchidaceae**

*Habenaria dilatata* (Pursh.) Hook.

*Spiranthes romanzoffiana* C. & S.

**Salicaceae**

*Salix chlorophylla* Anders.

**Polygonaceae**

*Oxyria digyna* (L.) Hill.

*Polygonum bistortoides* Pursh.

**Caryophyllaceae**

*Arenaria congesta* Nutt.

**Nymphaeaceae**

*Nymphaea polysepala* (Engelm.) Greene

**Ranunculaceae**

*Caltha leptosepala* DC.

*Ranunculus eschscholtzi* Schlecht.

*Ranunculus maximus* Greene

*Ranunculus reptans* L.

**Cruciferae**

*Draba columbiana* Rydb.

*Radicula alpina* (S. Wats.) Greene

*Smelowskia americana* Rydb.
Crassulaceae

Clementsia rhodantha (A. Gray) Rose
Sedum debile S. Wats.

Saxifragaceae

Saxifraga rhomboidea Greene

Rosaceae

Ivesia gordonii (Hook.) T. & G.
Potentilla diversifolia Lehm.
Sibbaldia procumbens L.

Violaceae

Viola macloskeyi Lloyd
Viola oxysepala Greene
Viola palustris L. albiflorum Neum.

Onagraceae

Epilobium anagallidifolium Lam.

Umbelliferae

Ligusticum tenuifolium Wats.

Ericaceae

Gaultheria humifusa (Graham) Rydb.
Kalmia microphylla (Hook.) Heller
Vaccinium occidentale A. Gray
Vaccinium scoparium Leiberg

Primulaceae

Dodecatheon tetrandrum Suksdorf.
Primula parryi A. Gray

Gentianaceae

Gentian parryi Engelm.
Swertia scopulina Greene

Polemoniaceae

Polemonium viscosum Nutt.

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Hydrophyllaceae

Phacelia alpina Rydb.

Scrophulariaceae

Castilleja luteovirens Rydb.
Castilleja rhexifolia Rydb.
Pedicularis groenlandica Retz.
Pedicularis paysoniana Fennell
Pedicularis racemosa Dougl.
Penstemon whippleanus A. Gray
Veronica wormskjoldii R. & S.

Campanulaceae

Campanula petiolata A. DC.

Compositae

Achillea lanulosa Nutt. var. alpicola Rydb.
Antennaria corymbosa E. Nels.
Arnica mollis Hook.
Erigeron salsuginosus (Richards) A. Gray
Erigeron ursinus D. C. Eaton
Senecio cymbalarioides Nutt.
Solidago ciliosa Greene
REFERENCES


